SPATIAL DISTRIBUTION OF TYPICAL LANDUSE TYPE IN UNDERDEVELOPED INDUSTRIAL CITIES

——A CASE OF JIALING DISTRICT IN NANCHONG CITY, SICHUAN PROVINCE

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KEY WORDS: landuse type; Jialing District; landscape ecology index; the fractal

ABSTRACT: The land-use pattern is one of the key study areas of the utilization of land resource、landscape ecology and the sustainable development, which has important implications for other areas such as the ecological environment, land-use, and isolation. Based on the second national land survey data, the application of landscape ecology theory and mathematical statistics, selecting the diversity index, evenness index, dominance index, fragmentation such as separation, we have studied the quantitative characteristics of the land-use structure in the suburbs. We have created a kind of distribution in the fractal structure model by using the fractal theory and have analyzed the complxity and stability of the types of land distribution, based on fractal dimension and stability indexes. The results showed that: the diversity and evenness index is smaller, the dominance index is larger, so that the land-use structure is uneven and the advantage land-use is cultivated land. The order of the separation is contrary to the fragmentation. The cultivated land is the most broken and the most concentrated land-use as well as the water area is the least broken and the most scatter land-use. Fractal dimension and stability index shows that the land-use distribution form is more irregular and less stable. The study conducted an analysis of the land-use structure of the urban in the underdeveloped cities, providing a reference for the ecological environmental protection, the rationalization of land-use.

1. INTRODUCTION

Research of land-use has a long history. Previously, many scholars research broadly focuses on land resources survey, zoning, classification, planning, evaluation and management of research and development and other fields(Fan et al., 2004). The study of land-use/land-cover change and its impact on global change mostly focuses on the typical area(Yu and Yang, 2002): one is the "hot spots", namely, a region with extremely active human activites and natural driving force, such as Shenzhen City(Shi et al., 2000), Beijing City(Gu, 1999), and the Yangtze River Delta(Yang, 2001). The other one is "fragile zone", in which the human activesync and natural driving forces are less active, such as Northeast China Transect(Kang et al., 2000), arid and semi-arid transition zone of the Yulin area(Zhang, 1999), and so on. Currently, with the rapid economic development and population growth, China is undergoing a rapid urbanization process(Chen, 1999). Many underdeveloped industrial regions in the west of China are the key areas of the further urbanization in the coming, and will play a crucial role in the process of industry transfer and urban function organic decentralization from developed areas, what’s more it is also hoped to influence and promote the development of underdeveloped areas (Liu and Zhu, 2012; Chenery et al., 1995; Guo, 2000). The suburb of underdeveloped industrial regions often locates between the periphery continuous built-up area of the city center and purely agricultural hinterland in which there are almost no citizen and agricultural land-use. It combines the urban characteristic and ecologiccal landscape of rural areas, and its population density is lower than the center, but higher than the surrounding rural areas(Gu et al., 1993). In the process of rapid urbanization, due to the mutual penetration and diffusion of economy and population between the urban and the rural, underdeveloped industrial areas are experiencing a profound evolution process with the fastest and the most notable land-use/land-cover, resulting in a variety of complex social and economic issues, including industrial restructuring and population migration. Therefore, the research of peri-urban land-use/land-cover change and corresponding pattern as well as its evolution process, is undoubtedly significant either in theory or practice (Wang et al., 2002).

In this paper, the typical underdeveloped western industrial city

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of Nanchong City, Sichuan Province was taken as a case study area based on the second national land-use survey data. We investigated the spatial distribution of typical landuse type based on landscape indices, fractal dimensions and stability index, which will help to analysis the rationality of land-use, and has important practical significance to guide the optimal allocation of regional land resource(Liu et al., 2009).

2. OVERVIEW OF THE STUDY AREA

Nanchong City locates in the north-central of Sichuan Basin, known as the center city in the north of Chengdu-Chongqing Economic Zone, and plays as a multifunctional center in economy, culture, transportation, commercial logistics and information in the northest of Sichuan, which also is one of the important port city in western China. As one of the three districts of Nanchong city, Jialing District locates in the southwest of Nanchong, belonging to the west bank, the middle reaches of Jialing River. Jialing district located in east longitude 105°45′-106°00′, north latitude 30°27′-30°52′, north to Shunqing District, south close to Wusheng county, west to Xichong and Pengxi countis, east to Gaoping District. In general the terrain of northwest is higher than southeast. From east to west, and from north to south, the region's landscapes are followed by low mountains, hills, with small flatland spreading among deep-cut hills. A transportation junction has formed in Jialing by roads, railways, waterways and air travel, with the convenient transportation, obvious location advantages and a broad development space. Jialing District is a big agricultural region, and the predominant type of agriculture is planting, known as the land of plenty. Jialing also is one of the national key ecological base of citrus and national commodity grain silkworm base. Jialing district is the national meat-pig base and the animal husbandry in this district is relatively developed. Now the followed industry in this region is begin to take shape, such as reeling, silk fabric, dyeing, clothing, knitting, molding machinery and other companies, while the food, grain, oil, auto parts and other commercial and industrial enterprises have already started, with an ascendant township enterprises.

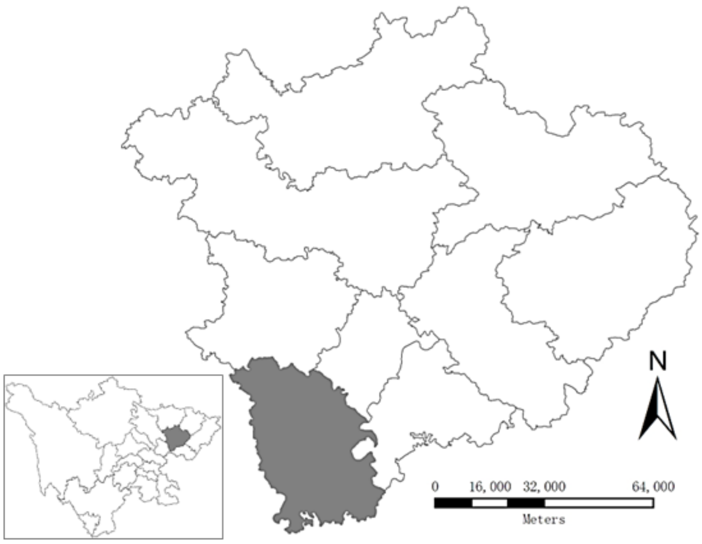

Figure 1. The location of Jialing district in Nanchong, Sichuan Province

3. MATERIALS

Based on the reliability and availability of data, we used the land-use data of Jialing District for the spatial structure investigation. The data was produced by Second National Land Use Survey, and the research area locates in Nanchong City, Sichuan Province. According to the research objectives and present condition of land utilization, the study uses the Chinese land resources classification system(Wu and Guo, 1994; Zhang et al., 2011), dividing the landuse types into 5 different types: the farmland (including the paddy field and dry land), the garden (including orchard and other garden), the wood land (including forest land, shrub land, and other types), the transportation land (including the land for railway and highway), the water (mainly for the reservoir of the water).

4. METHODS

4.1 Indices of landscape pattern

In a specfic area, the quadrats of all kinds of landscape types are organically unifies with staggered distribution, which forms a landscape mosaic(Xiao, 1991), Xu et al., 2001). The landscape mosaic is a geographical entity with distinct morphological characteristics and function relation, which furtherly have the correlation between the structure and function. Through analysis of the landscape pattern indices, we can acquire the changes pattern, mechanisms of different land-use types and its impact on regional ecosystem(Zhan et al., 2011). We use the statistical indicators, diversity index, uniformity, dominance, fragmentation, isolation together to describe regional land-use structure quantitatively and comprehensive (Yue et al., 2002). The indicators and its interpretation are as followed.

(1) Basic statistical indicators are used to calculate the area of different land types and its percentages(Chen et al., 2001).

(2) Diversity index, is the comprehensive description of abundance and uniformity degree about land-use type. The formula is as followed(Turner and Gardner, 1991; Zhang et al., 2000):

$$H = -\sum_{i=1}^{S} P_i \ln P_i \tag{1}$$

Where S represents the number of land types. P_i represents as a proportion of the i^{th} class land area to the total land area and H is the diversity index of land-use type. Generally the greater the H value is, the greater the divetsity of land-use type will be.

(3) Uniformity reveals the uneven degree about the area for the distribution of various patches in the land-use and the formula is as followed(Zhan et al., 2011):

$$E = H / H_{\max} \tag{2}$$

Where H is same with the formula (1), $H_{\max} = \ln S$ is the largest diversity of the land-use distribution. When the E approach to 1, the uniformity of the distribution of land type tends to be the largest.

(4) Degree of dominance is used to measure the dominant degree of one or a few land types among the land-use structure. The formula is as followed(Turner and Gardner, 1991; Zhang et al., 2000):

$$D = H_{\max} + \sum_{i=1}^{S} P_i \ln P_i \tag{3}$$

Where S is same with the formula (1). D is the degree of dominance. The greater D values is, the dominant degree of one or a few land types among the land-use structure tendes larger.

(5) Degree of fragmentation is used to measure the number of patches within unit area and it means the broken degree of the land patches. The formula is as followed(Turner and Gardner, 1991; Zhang et al., 2000):

$$F = \sum_{k=1}^{S} n_k / A \tag{4}$$

Where S is same with the formula (1), and n_k is the patches number of the k^{th} land type. A is the total land area and F is the degree of fragmentation. The greater the F value is, the cut degree of land will tend to larger, which implies a more broken land patches.

(6) Degree of separation reflects the distribution of the different individual patches among the same land type in one region. The formula is as followed(Xiao, 1991):

$$I_k = \frac{1}{2}\sqrt{\frac{n_k}{A}} \Big/ \frac{A_k}{A} \tag{5}$$

Where I_k is the separation degree of the k^{th} land type, meanwhile n_k and A is same to the formula (4), while A_k is the area of the k^{th} land type. For one land type, the separation degree indicates the degree of separation and cut by other land type or corridor.

4.2 Fractal model

Research shows that land quadrat is one of the most typical fractal geometry object in the nature(Xu et al., 2001; Li, 2000). The fractal theory was used to depict the morphological structure of the various land types for quantitative exploration(Yue et al., 2002). The fractal theory used in landuse structure can be concluded into the following types, such as fractal dimension computation of different kind landuse, methods used in landuse fractal research, fractal depiction of landuse variation and fraction models used in regional landscape pattern etc(Zhu and Cai, 2005). This paper mainly analyzes the fractal characteristics of the land types in Jialing District. The formula (6) was used to establish the relationship between the perimeter and area of different land types in Jialing District, and to calculate the spacial structure fractal dimension of every land types.

$$A = kP^{\frac{2}{D}} \tag{6}$$

Where A is the area of a patch and P is it's perimeter, while D is the fractal dimension with k being a undetermined constant. After the double logarithmic transformation, modification of formula (1) can be modified into formula (7) :

$$\log A = \frac{2}{D}\log P + C \tag{7}$$

By formula (7) the relationship can be established between the perimeter and area of land patch. The greater D value is, the more complex of the mosaic structure in the space will be. When D equals to 1.5, it means a state of random motion, which is similar to Brownian motion implying the most unstable spatial structure of specific landuse types. If D is closer to 1.5, it often implies the spatial structure tending to unstable(Zhu and Cai, 2005; Xu et al., 2001). Then the stability index of the landscape patches can be defined as followed(Xu et al., 2001):

$$SK = |1.5 - D| \tag{8}$$

5. RESULTS AND DISCUSSION

5.1 Analysis of landscape pattern

In order to reveal the structure characteristics of land use in Jialing District, we statistic the area and the area percentage of every land types, and use the formula (1)-(5) to calculat the following indices, including diversity, uniformity, degree of dominance, fragmentation and separation.

Land types	Area (km^2)	Percentage (%)	Diversity index	Uniformity	Dominance degree	Fragmentatio (piece/km^2)	Separation
Cultivated land	1010.9930	93.8977	0.2839	0.1764	1.3256	1.0430	0.5438
Garden land	16.1893	1.5036				0.1282	11.9049
Forest land	42.9572	3.9897				0.3548	7.4647
Transportation land	5.8579	0.5441				0.0984	28.8353
Waters	0.6982	0.0649				0.0121	84.7190
Summation	1076.6957	-				1.6365	-

Table 2. Quantitative characteristics of land-use structure

From Table 2 we can know that, in the Jialing District, the diversity index and the uniformity are lesser while the degree of dominance being larger, which reveals an uneven land-use structure with dominated land type. The major land type is cropland with the area accounting for 93.8977% of the total area, and the second big area is wood land and garden land.

The total degree of fragmentation is 1.6365 piece/ km^2, and the order of different landuse type according to fragmentation degree is that: cultivated land > forest land > garden land > transportation land > waters. This means that the cultivated land's fragmentation is relatively large for almost 1.043 piece/km^2, while the water's fragmentation is relatively small, for 0.0121piece/km^2. However, the order of the separation degree is just in the opposite part: waters > transportation land > garden land > forest land > cultivated land. This means that the patches of water is the most disperse while cultivated land is the most concentrated.

5.2 Analysis of fractal model

According to the formula (7), we can establish the relationship between the perimeter and area of land types in Jialing District, which is so called the fractal dimension of land types. Due to the large amount of landuse type which can be use to calculate fractal dimension, Figure 3 only take the perimeter-area double logarithmic relationship of orchard as an example.

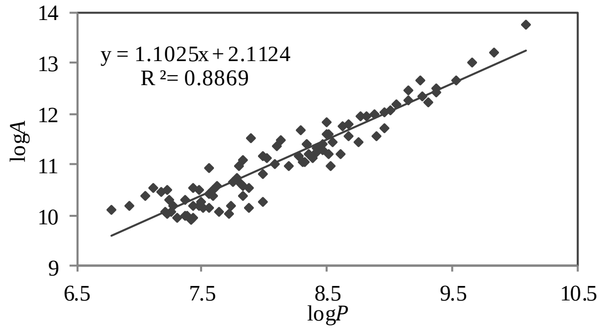

Figure 3. Plots of log$A$－log$P$ of orchard

According to the same calculate process, we can get the perimeter-area double logarithmic relationship of other land types, and we further evaluate the fractal dimension of all types (Table 4).

Land types	*D*	*SK*	Land types	*D*	*SK*
Cultivated land	N/A	N/A	Paddy field	N/A	N/A
			Dry land	1.9231	0.4231
Garden land	1.7404	0.2404	Orchard	1.8141	0.3141
			Other garden	1.6667	0.1667
Forest land	1.6154	0.1154	Forest land	1.6807	0.1807
			Shrubland	1.2048	0.2952
			Other woodland	1.9608	0.4608
Transportation land	N/A	N/A	Railway land	N/A	N/A
			Highway land	N/A	N/A
Waters	1.7241	0.2241	Reservoir	1.7241	0.2241

Table 4. The fractal dimension of land-use types

According to Table 4, we can get the following conclusions.

1) The linear relationships between parameters and area after double logarithmic transformation of the cultivated land and transportation land fit poorly, we do not get any valuable information.

2) Based on the firstly classification of land use types, the order of the complexity degree is that: garden land > water > forest land with the close fractal demention over 1.6. Due to the fractal dimension of the first classification of landuse types is an average fractal dimension of the second classification, so that the results have a certain degree of deviation. Taking the woodland as an case, the fractal dimension of the other woodland is the maximum equal to 1.9608, while the shrub is the smallest fractal dimension of 1.2048, which results in the total fractal dimension of the woodland is relatively small. When it comes to water, since swag (a sub-type of water) did not obey the parameter-area fractal dimension, we do not take it into account. Thus, the experimental results of fractal dimension is just the same as the reservoir surface fractal dimension. The order of the stability degree is similar to that of the complexity degree, that is if the fractal dimension is closer and smaller, the land type will be more unstalbe.

3) According to the second classification of landuse type, the degree of complexity (D) sorted as followed: other forest land > dry land > orchard > reservoir > forest land > other garden land > shrub. Therefore the mosaic structure of the other forest land is the most complex one, while the shrub is the simplest one. The order of the stability degree can be described as: other forest land > dry land > orchard > shrub > reservoir > forest land > other garden land. So it is obvious that the mosaic

structure of the other forest land is the most stable one, while the other garden land being the most unstable.

6. CONCLUSION

Based on the mathematical statistics and landscape ecology theory, many indices such as the diversity index, evenness index, dominance index, fragmentation and separation are chosen to study the quantitative characteristics of the land-use structure in the suburbs. A kind of fractal model has been established to analyze the complxity and stability of the types of land distribution, which is based on fractal dimension and stability indexes. The results shows that the diversity and evenness index is smaller while dominance index is larger, so that the land-use structure is uneven and the predominant type is cultivated land. The order of the separation is contrary to the fragmentation. The cultivated land is the most broken and the most concentrated land-use as well as the water area is the least broken and the most scattered land-use type. Fractal dimension and stability index shows that different landuse distributed irregularly with a relatively less stable. The reasons may be that the city of Nanchong is an underdeveloped industrial city whose agriculture accounts for larger proportion than other, so the area of arable land has become one of the governed class in the area.

This article focuses on the land-use structure of less-developed suburbs of Jialing District in Nanchong City, and the research method and the conclusions above on this kind areas will provide a reference for environmental protection and the land-use rationalization in other similar cities.

However, a static landuse data was used based on Second land survey data in this paper when analysis Jialing landuse pattern, variation of the landuse spatial pattern is missed due to the lack of data. The following studies need to further discuss the developed distribution characteristics of the land-use pattern not only on spatial scale but also on timescales.

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